HOWSER

Loss of Head in Pump Valves

Civil Engineering

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LOSS OF HEAD IN PUMP VALVES

BY

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THESIS

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IN

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COLLEGE OF ENGINEERING

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THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

THERON ROBINSON HOWSER

ENTITLED LOSS OF HEAD IN PUMP VALVES

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE

DEGREE OF Bachelor of Science in Civil Engineering

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Instructor in Charge.

APPROVED: Ira O. Baker.

HEAD OF DEPARTMENT OF Civil Engineering

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LOSS OF HEAD IN PUMP VALVES.

The object of this thesis is to determine the loss of head in pump valves, both the amount of and, if possible, the nature of that loss which occurs when water flows through a pump valve under ordinary conditions. In this connection an attempt will be made to determine the best conditions for the valves as they are now and to modify the valves tested with a view to making improvements in them. There is a loss of head in pump valves and if by some means this loss could be decreased without producing any other effects upon the action of the valve, then a great deal of energy could be saved. To determine whether this loss of head is great enough to have serious effect upon the efficiency of the pump, and to arrive , if possible, at some conclusions as to the nature of this loss and the effect of the shape of the valve upon it is the object of this thesis.

In this thesis the apparatus illustrated on the following pages was used. It was designed and constructed by Mr. W. E. Brewer, University of Illinois, 1907. The tests were made in the Hydraulics Department of the Theoretical and Applied Mechanics Laboratory of the University of Illinois. The water is furnished by a four by sixty foot stand pipe, the water in which is maintained at any given level by an adjustable governor on the pump which fills the stand pipe. The velocity of discharge through the valve was controlled by a valve on the discharge pipe at A (Plate I) or by means of a gate valve on the inlet at B. The rate was measured by measuring the rise in level in a calibrated pit in a

given time. Some of the first tests were made by regulating, first at A and then at B, but it was soon decided that the method by regulation at A was the nearer to the actual condition. For comparison see Curve Sheet No. 5. In the case where the rate was regulated at the inlet the pressure on the far side of the valve was almost zero, while the regulation at the outlet, the pressure on the far side was very high, thus very nearly approximating actual conditions.

The rise of the valve from its seat was measured by the pointer P (Plate 1). The lever arm x, y, is equal to the lever arm y, z, and the fork is connected to the end z, so that it rises when the valve disk rises. The loss in head was determined by means of a mercury differential gage, one leg of which was connected above the valve seat, and the other below it. This gage was made of two pieces of one quarter inch glass tubing connected with a section of rubber tubing, and filled with mercury to the middle point. There was also a Bourdon Gage connected at both points. The exact time of flow through the valve had to be determined, so it was necessary to have a quick action valve at C, in addition to the other, by means of this valve a flow could be started and stopped instantly.

The apparatus used to determine the relation of compression in the valve spring to lift of the valve seat, is shown in (Plate II), and the drawing is sufficient explanation of its action.

According to the statements of Mr. Brewer in his thesis, the loss of head in a pump valve may be made up of (a) entrance head, which is so small as to be negligible; (b) friction head, which is very small; (c) impact and eddy losses, change of direction of flow, and head required to compress the spring and ; (d) velocity

head.

The tables from which the curves are plotted show the relations of the various quantities one to the other. The first column in the table gives the rate of flow through the valves in cubic feet per second. The second column is obtained from the first by dividing by the smallest area of open cross section in a horizontal plane, and is therefore the maximum linear velocity through the valve in feet per second. The third column is the loss of head, in feet, and is simply the reading of the differential gage. The fourth shows the distance in inches, that the valve disk is raised above the seat. The fifth column is the compression in the spring in pounds, and shows the actual amount of force which must be exerted to open the valve to that point.

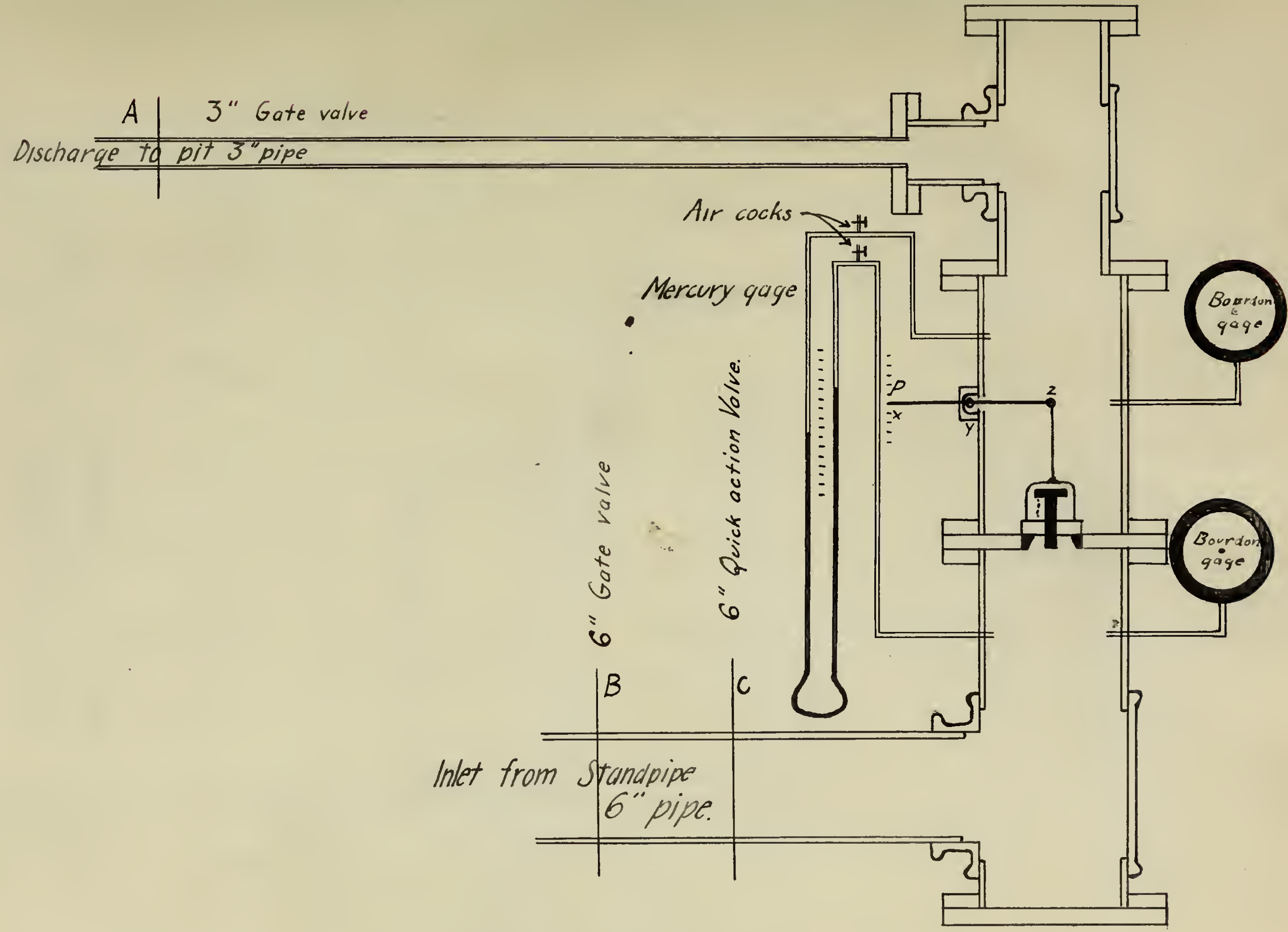
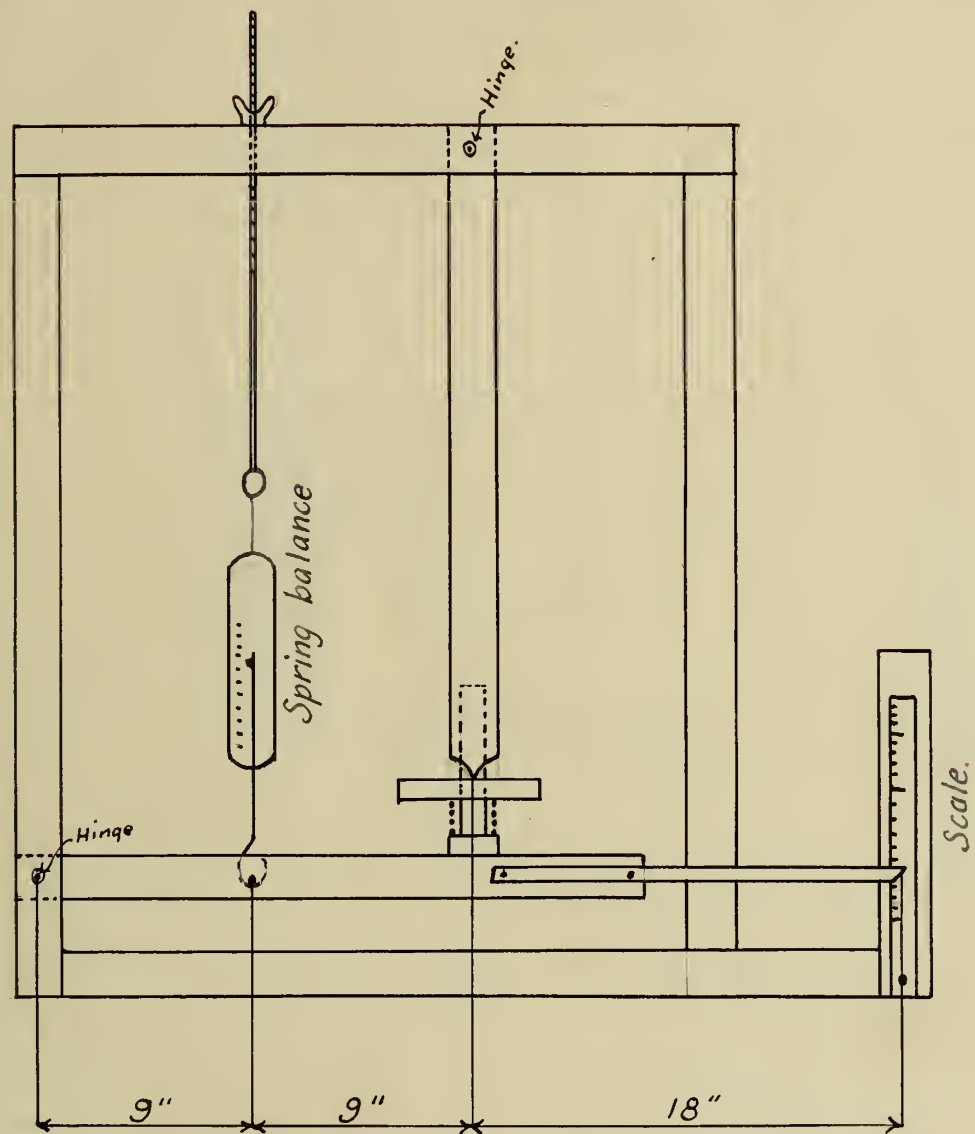


Plate I. General arrangement of apparatus.

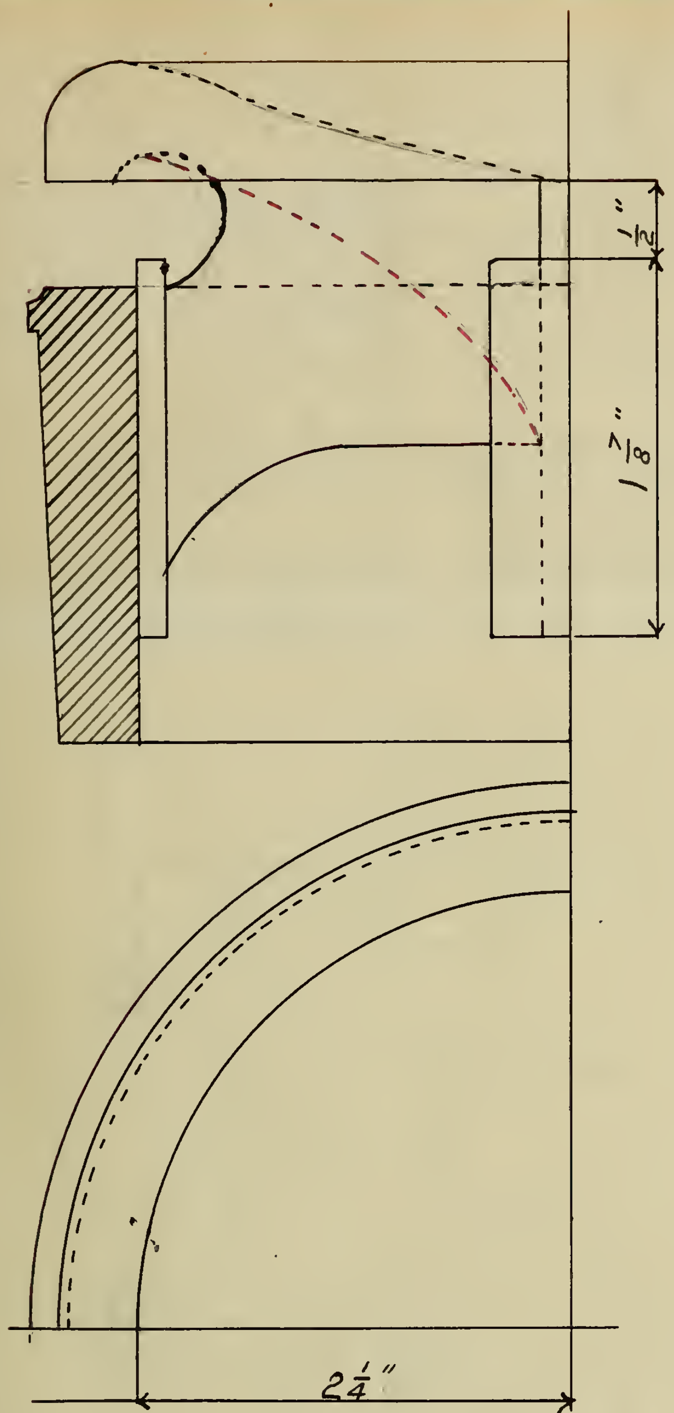
Plate II.



Apparatus for determining relation of valve lift and spring compression.

LIST OF VALVES TESTED.

Number.	Name and kind.	Size, inches.
1	Heisler, Spring.	3.00
2	" "	3.75
3	" "	2.75
5	Union Steam Pump Co., Spring.	3.00
6	Snow, Spring.	3.00
8	" "	3.25
10	Epping Carpenter, Spring.	6.00
12	" " "	5.00
14	" " Gravity	4.50
16	" " Spring.	4.00



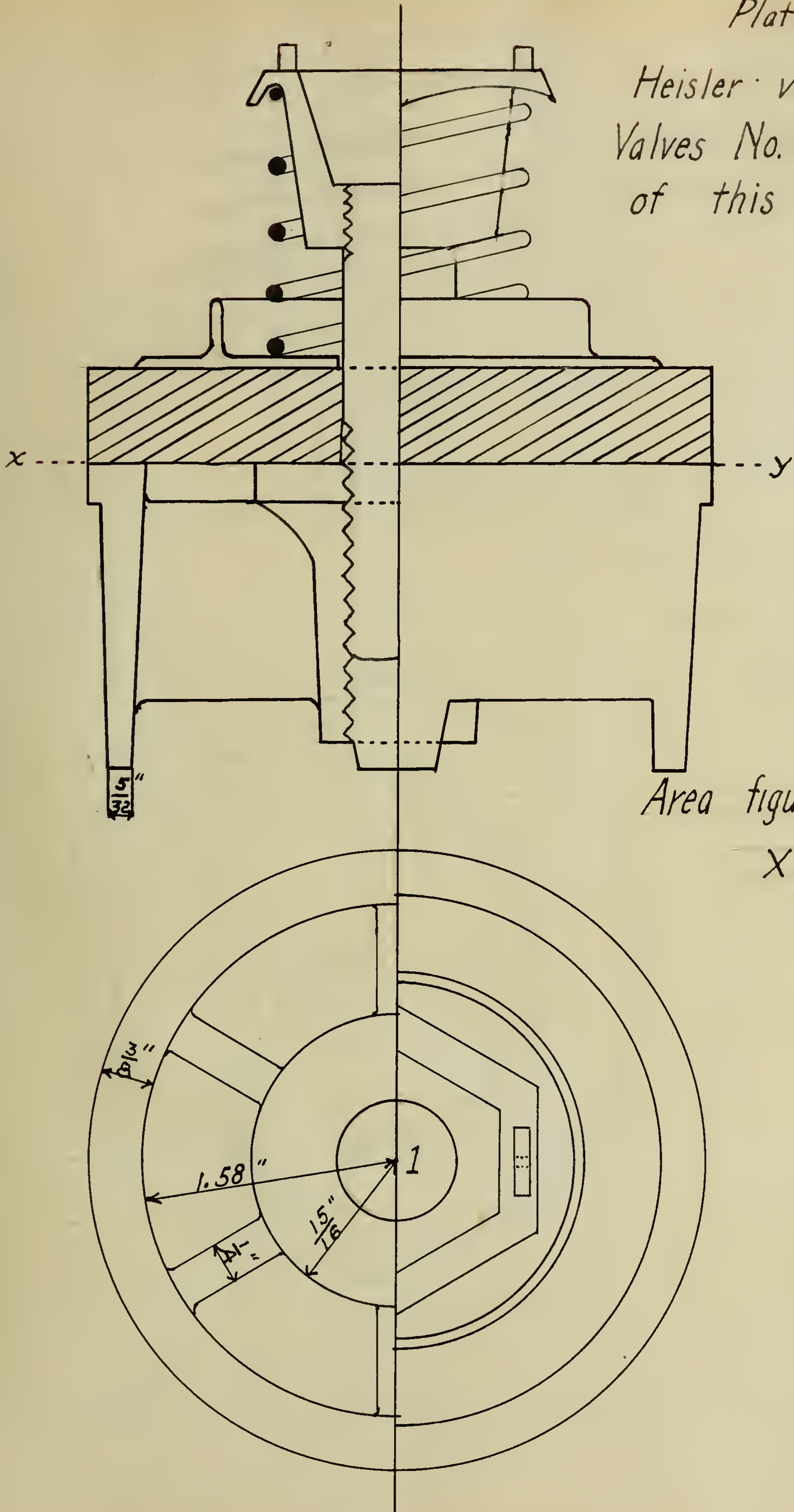
Epping Carpenter, gravity, No. 14

Area of opening, horizontal = 15 □"

Max. lift = 1.21"

Modified by addition of cement to red line.

Heisler valve No. 1.
Valves No. 1, 2, & 3.
of this type.

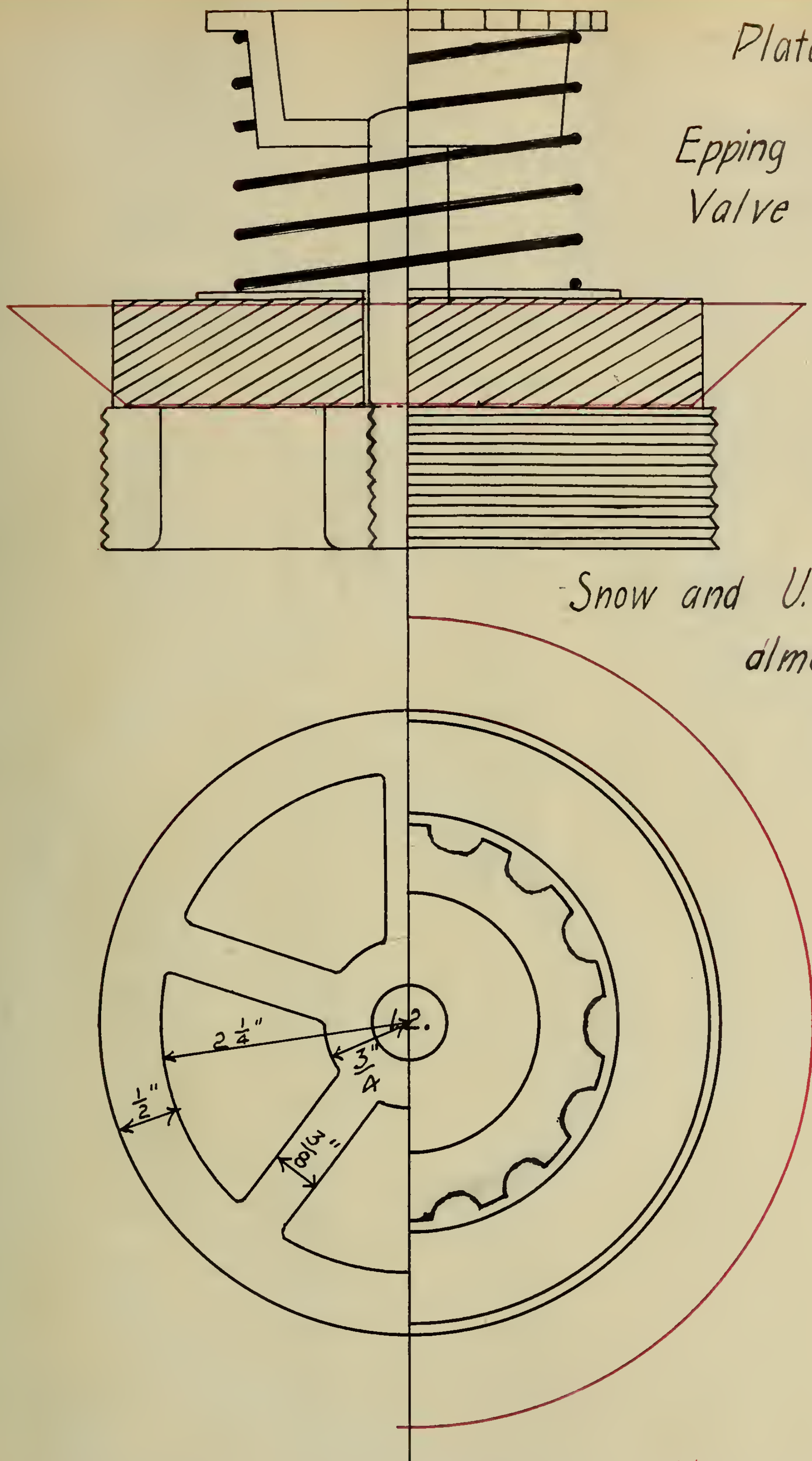


Area figured in plane, X, Y.

Scale 1" = 1"

Plate. VI.

Epping Carpenter Valve No. 12.



Valves No. 10, 12, & 16, of this type.

Snow and U.S.P.Co valves almost the same.

See Brewers thesis.

Red lines show modification which reduced loss.

OBSERVED DATA.

Valve No. 1. Heisler. Reading of Diff Gage ?

Quantity Cu. Ft/Sec.	max. Velocity Ft./Sec.	Loss in Head. Feet.	Valve Opening "	Spring Compression #
.005	.13	.68	.01	4.7
.025	.66	1.23	.03	4.7
.045	1.20	1.63	.05	4.7
.021	.56	1.36	.01	4.8
.060	2.26	1.91	.04	4.9
.065	1.73	1.77	.06	4.7
.081	2.16	1.91	.12	4.8
.085	2.26	1.91	.09	4.9
.115	3.06	1.91	.12	4.8
.121	3.23	1.91	.10	4.9
.141	3.76	1.50	.06	4.9
.135	3.60	1.91	.12	5.0
.166	4.42	1.97	.17	4.9
. 181	4.83	1.91	.20	5.5
.186	4.96	2.04	.20	5.0
.211	5.65	2.18	.25	4.7
.221	5.89	2.31	.51	5.5
.251	6.69	2.72	.53	4.8
.276	7.36	3.40	.62	5.8
.441	11.73	9.11	.62	5.8

OBSERVED DATA.

Valve No.2. Heisler.

Quantity Cu./Ft./Sec	Velocity Ft./Sec.	Loss in Head.Feet.	Valve " Opening	Spring # Compression
.031	.72	8.60	.36	26
.041	..92	5.74	.02	18
.125	2.82	6.55	.04	19
.246	5.55	.6.96	.14	21
.411	9.26	7.93	.25	23
.502	11.31	8.20	.33	26
.573	12.90	9.56	.47	28
.573	12.90	6.70	.04	19
.633	14.25	11.49	.47	28
.830	19.70	8.60	.36	26
.745	16.78	10.59	.47	28

OBSERVED DATA.

Valve No.3. Heisler.

Quantity Cu. Ft./Sec.	Velocity Ft./Sec.	Loss in Head. Feet.	Valve Opening "	Spring Compression #
.005	.20	1.64	.02	3
.0104	.47	2.03	.01	3
.041	1.85	2.73	.06	3
.071	3.20	3.00	.05	3
.071	3.20	3.00	.05	3
.085	3.82	3.00	.13	3.5
.120	5.40	2.73	.18	3.5
.151	6.86	2.59	.27	3.5
.161	7.21	2.59	.29	3.5
.161	7.25	2.59	.30	3.5
.221	9.95	3.42	.27	3.5
.231	10.40	3.55	.54	4
.281	12.65	3.96	.54	4
.342	15.40	6.01	.54	4
.361	16.25	3.96	.54	4
.461	20.08	14.60	.54	4

OBSERVED DATA.

Valve No.5. Union Steam Pump Co.

Quantity Cu. Ft./Sec.	Velocity Ft./Sec.	Loss in Head.Feet.	Valve Opening "	Spring Compression #
.08	1.6	3.0	.10	8
.17	3.5	3.6	.21	9
.30	6.2	4.4	.49	14
.35	7.3	4.3	.31	11
.35	7.3	5.6	.45	13
.42	8.7	6.9	.75	16
.48	10.0	9.5	.88	18
.57	11.9	9.9	.88	18
.80	i6.5	24.5	.88	18
.82	17.0	24.8	.88	18

Regulated at discharge, first series at inlet.

.016	.43	2.58	.20	11
.134	3.41	3.54	.29	12
.125	3.20	3.56	.29	12
.191	4.90	4.21	.40	14
.201	5.94	4.90	.47	15
.401	10.27	6.12	.60	15
.391	I0.00	7.21	.65	16
.401	10.27	7.89	.83	20
.537	13.75	11.70	.88	21
.685	17.50	13.35	.88	21
.720	18.40	22.40	.88	21

OBSERVED DATA.

Valve No.5 . Union Steam Pump Co.

Quantity Cu. Ft./Sec.	Velocity Ft./Sec.	Loss in Head.Feet.	Valve Opening "	Spring Compression #
.042	1.07	1.77	.20	11
.085	2.18	2.73	.25	11
.215	5.52	3.82	.29	12
.286	7.35	5.32	.50	15
.587	14.10	11.20	.88	21
.557	14.30	26.60	!88	21

.Valve No.6. Snow.

Quantity Cu. Ft./Sec.	Velocity Ft./Sec.	Loss in Head.Feet.	Valve Opening "	Spring Compression #
.15	3.1	.9	.22	6
.19	3.9	1.5	.36	9
.22	4.6	2.6	.50	9.9
.24	5.0	2.2	.37	9
.84	16.9	20.8	.57	13.5
.84	16.9	19.5	.57	13.5
.85	17.0	21.4	.57	13.5
.85	17.o	21.5	.57	13.5
.88	18.3	23.8	.57	13.5

OBSERVED DATA.

Valve No. 8. Snow

Quantity Cu. Ft. /Sec	Velocity Ft./Sec	Loss in Head.Feet.	Valve Opening "	Spring Compression #
.020	.96	3.01	.02	5
.020	.96	2.87	.02	5
.060	2.89	3.96	.06	5
.115	5.56	3.96	.10	5
.140	6.72	4.51	.17	5
.165	7.91	4.51	.20	7
.201	9.60	4.92	.23	7
.206	9.80	5.05	.24	7
.286	13.70	5.74	.33	9
.342	16.40	6.96	.37	10
.457	21.90	16.40	.37	10
.457	21.90	16.40	.37	10
.505	24.20	9.55	.37	10
.595	28.50	13.34	.37	10

Valve No. 10 Epping Carpenter.

.022	.128	.82	.02	5
.061	.355	.82	.05	5
.061	.35	.95	.02	5
.115	.67	.83	.08	5
.130	.75	.95	.08	5
.165	.96	.82	.13	5.5
.216	1.26	.82	.17	6
.271	1.57	.95	.32	6
.361	2.10	1.36	.52	6

OBSERVED DATA.

Valve No. 12. Epping Carpenter

Quantity Cu. Ft./Sec.	Velocity Ft./Sec.	Loss in Head. Feet.	Valve Opening "	Spring Compression #
Valve Normal.				
.101	.85	1.02	.01	2.25
.196	1.67	1.12	.17	3.50
.346	2.94	1.63	.46	6.00
.527	4.48	3.14	.55	6.25
.618	5.26	4.65	.55	6.25
.753	6.40	6.14	.55	6.25
.863	7.34	9.27	.55	6.25
.905	8.68	9.41	.55	6.25
Valve modified by substitution of beveled disk.				
.100	.85	.95	.05	2
.161	1.37	1.02	.10	2
.201	1.72	1.09	.12	2
.276	2.35	1.29	.25	3
.246	2.94	1.43	.39	4
.406	3.45	1.64	.45	4
.548	4.56	1.64	.45	4
.760	6.46	5.05	.61	6
.860	7.30	6.82	.61	6

OBSERVED DATA.

Valve No. 12. Epping Carpenter.

Quantity Cu. Ft./Sec.	Velocity Ft./Sec.	Loss in Head. Feet.	Valve Opening "	Spring Compression #
Valve rigidly held open at .90 inches.				
.271	2.31	.13	.90	00
.372	3.16	.82	.90	00
.491	4.17	1.64	.90	00
.523	4.44	1.60	.90	00
.587	5.00	2.32	.90	00
.750	6.37	3.28	.90	00
.814	6.91	7.37	.90	00
.877	7.46	4.92	.90	00
.900	7.65	5.46	.90	00
.955	8.11	6.14	.90	00
1.000	8.50	1.64	.90	00
1.030	8.75	6.69	.90	00
1.130	9.61	10.10	.90	00

OBSERVED DATA.

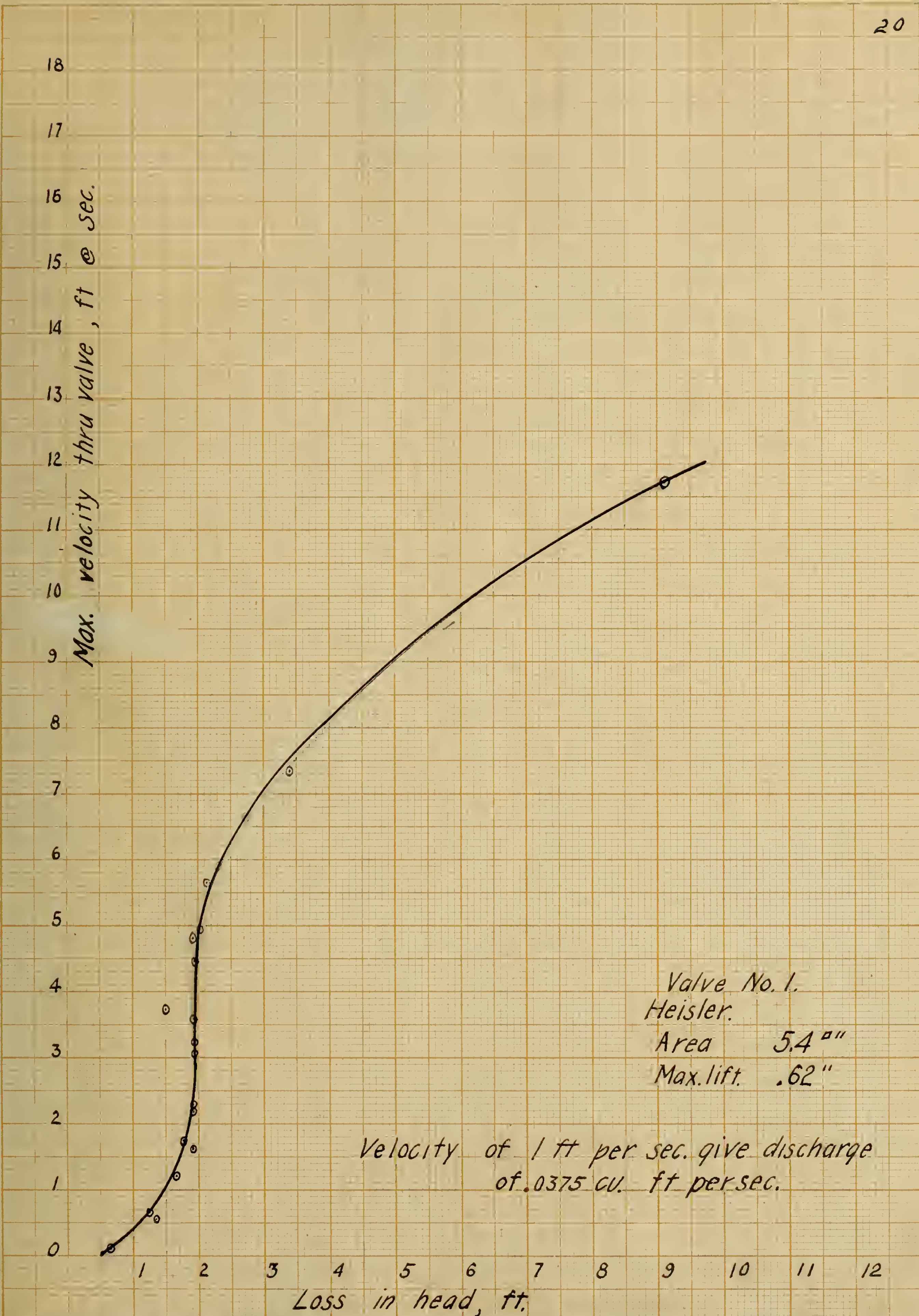
Valve No. 14. Epping Carpenter. Gravity.

Quantity Cu. Ft./Sec.	Velocity Ft./Sec.	Loss in Head, Feet.	Valve Opening "	Weight Of Cover.
.0105	.104	.571	.02	4.75#
.0351	.338	.721	.06	
.0410	.395	.734	.07	
.115	1.105	.680	.08	
.161	1.55	.680	.48	
.210	2.02	.639	.68	
.346	3.33	.666	1.30	
.502	4.84	1.672	1.45	
.550	5.30	1.672	1.64	
.684	6.56	2.720	1.64	
Same valve modified by filling with cement.				
.0335	.322	.68	.03	5.00 lbs.
.091	.880	.68	.23	
.092	.885	.68	.23	
.251	2.41	.68	1.21	
.352	3.38	.82	1.21	
.407	3.91	1.36	1.21	
.517	4.96	2.60	1.21	
.502	4.84	1.50	1.21	
.552	5.01	6.28	1.21	
.602	5.79	3.82	1.21	

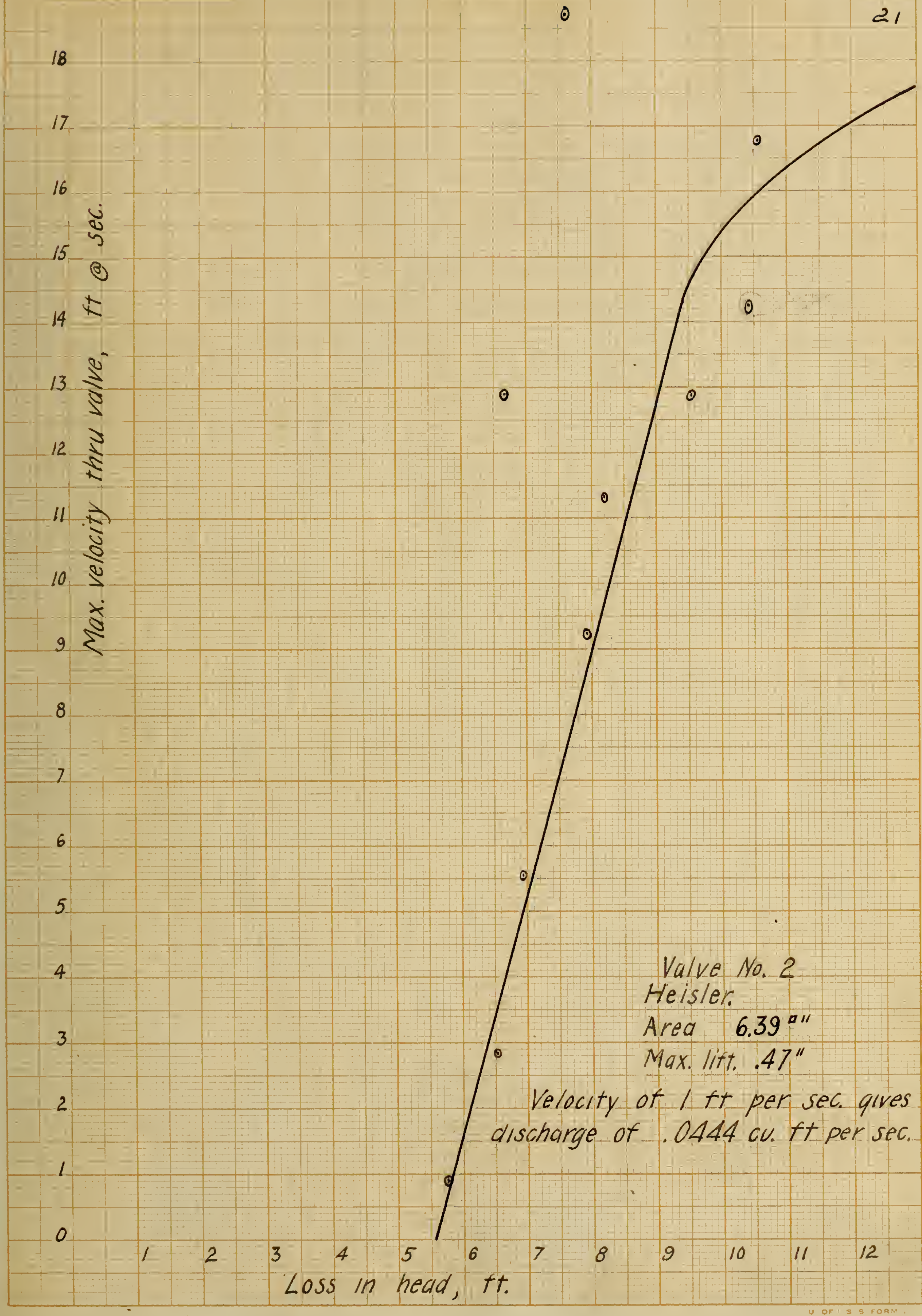
OBSERVED DATA.

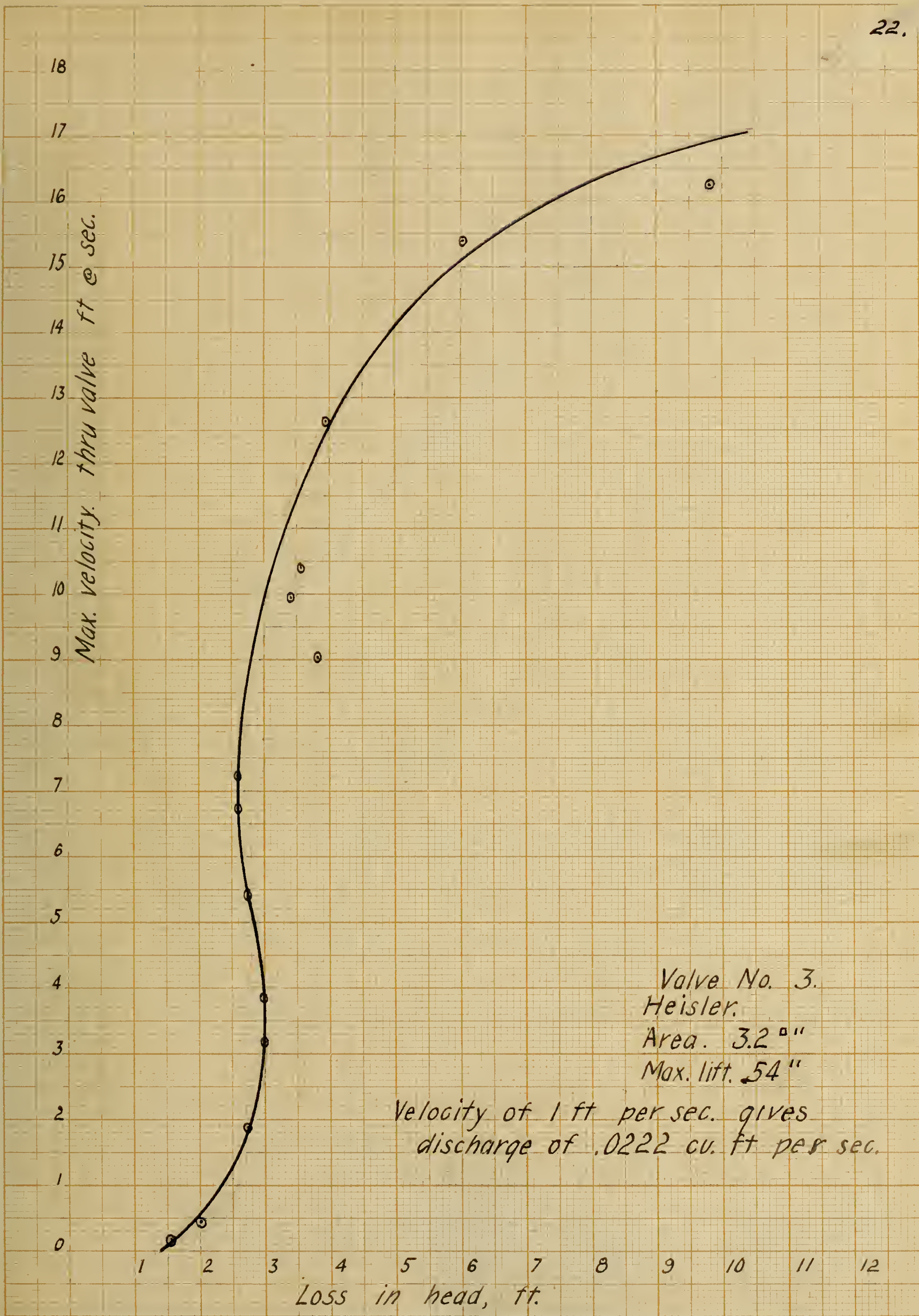
Valve No. 16. Epping Carpenter.

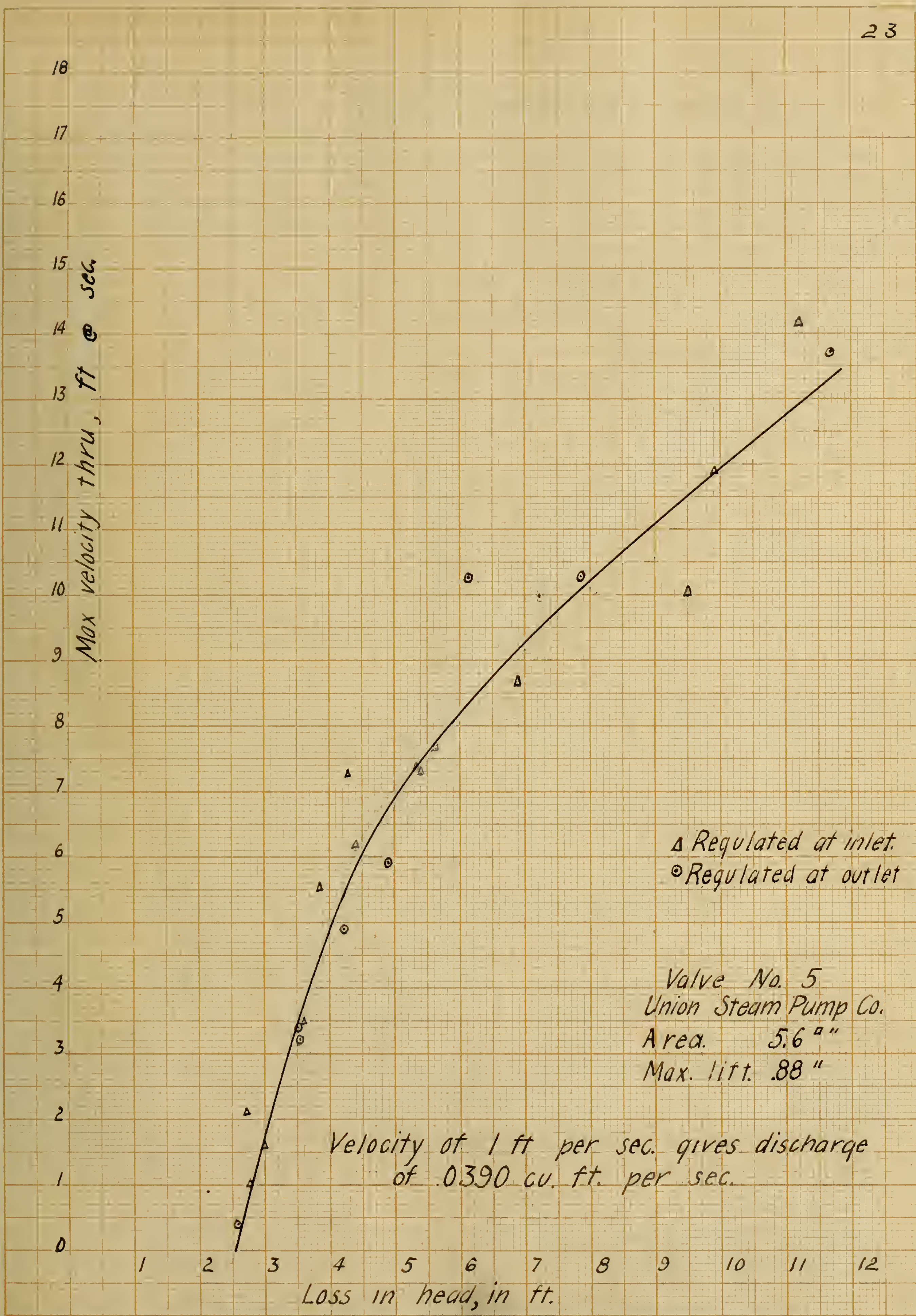
Quantity Cu. Ft./Sec.	Velocity Ft./Sec.	Loss in Head. Feet.	Valve Opening "	Spring Compression #
.005	.077	1.63	.01	7 lbs
.040	.61	2.04	.02	7
.045	.692	1.91	.03	7.5
.072	1.11	2.18	.07	7
.095	1.47	2.32	.08	8
.135	2.07	2.32	.13	8.5
.198	3.04	2.73	.19	9
.256	3.94	2.73	.24	9.5
.346	5.31	3.41	.33	10
.411	6.31	4.64	.37	10.5
.511	6.86	5.73	.37	10.5
.566	8.71	8.19	.38	10.5
.697	10.71	15.00	.38	10.5
.857	13.19	16.23	.38	10.5



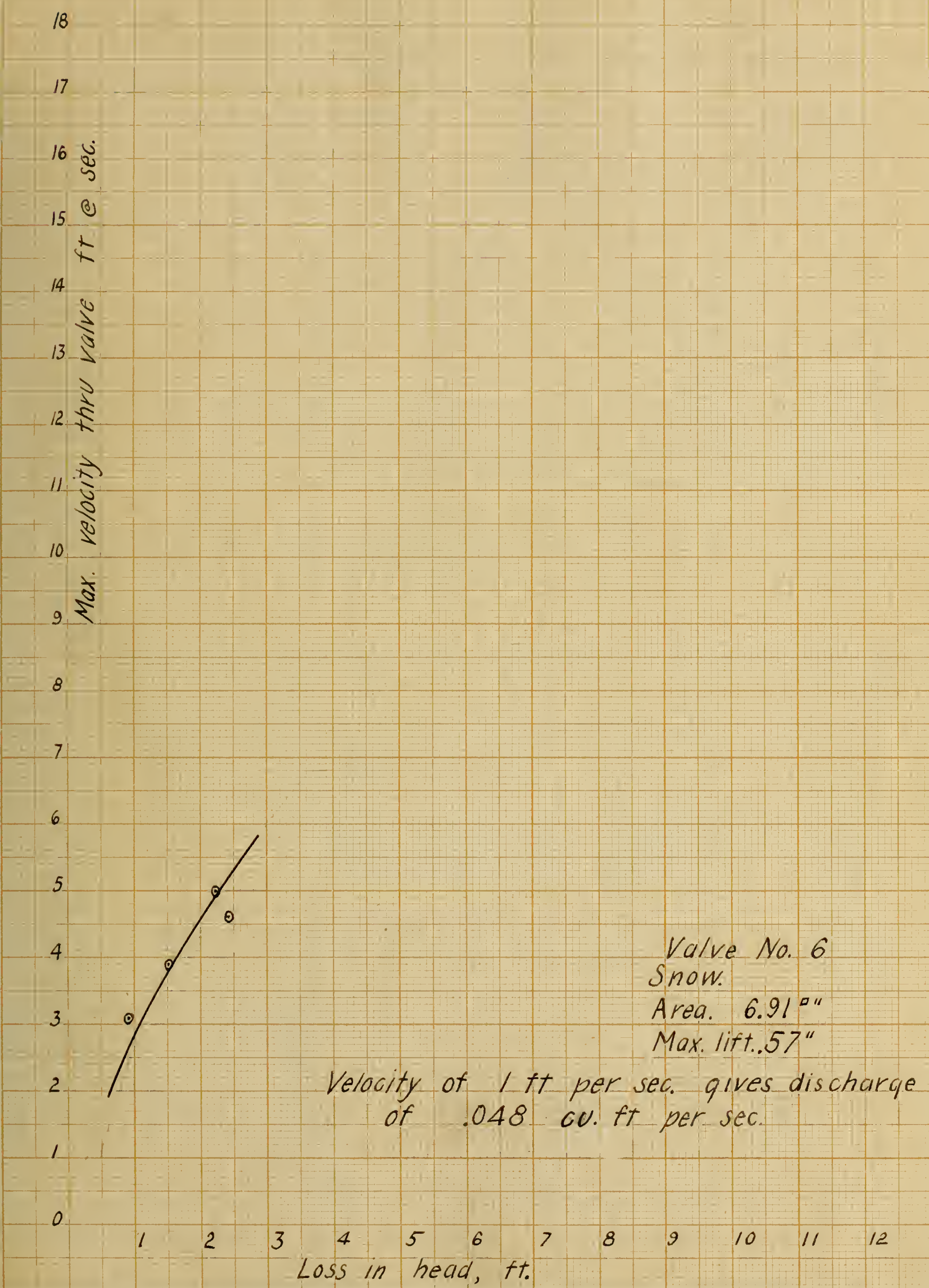
Max. velocity thru valve, ft @ sec.
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
1
2
3
4
5
6
7
8
9
10
11
12
Loss in head, ft.
Valve No. 1.
Heisler.
Area 5.4 □"
Max. lift .62"
Velocity of 1 ft per sec. give discharge
of .0375 cu. ft per sec.

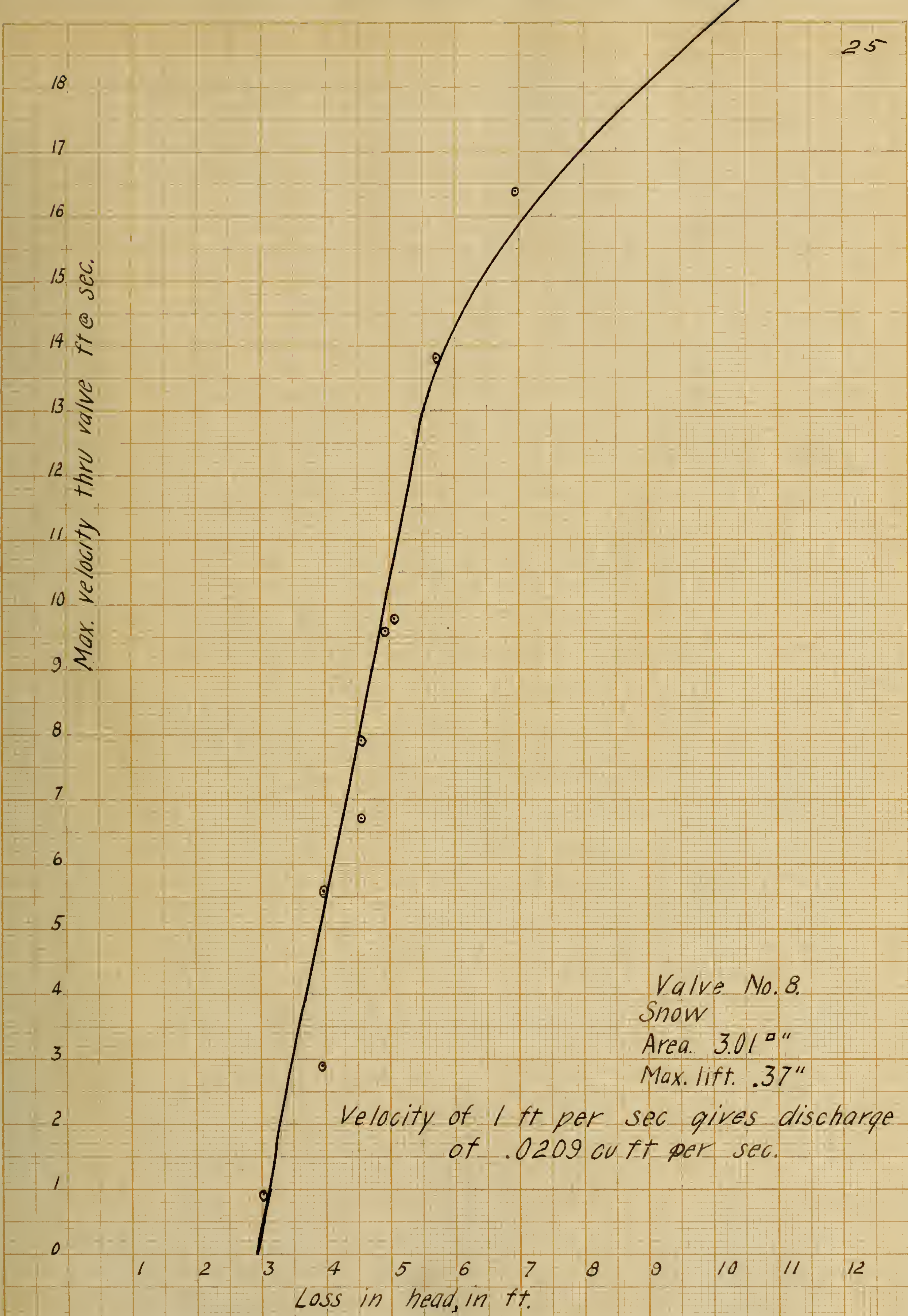

Max. velocity thru valve, ft @ sec.
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
1
2
3
4
5
6
7
8
9
10
11
12
Loss in head, ft.
Valve No. 2
Heisler.
Area 6.39 □"
Max. lift. .47"
Velocity of 1 ft per sec. gives
discharge of .0444 cu. ft per sec.

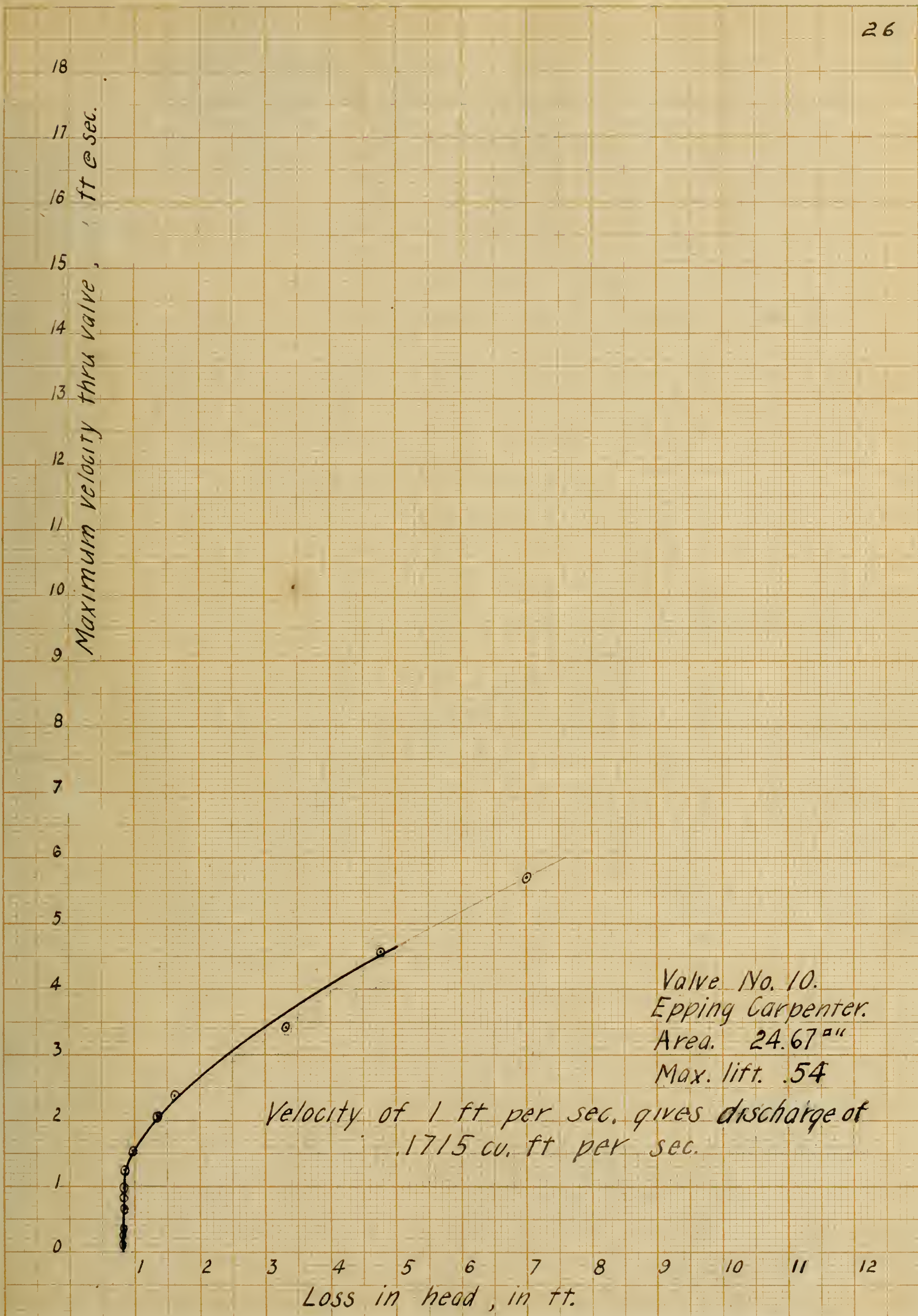

Max. velocity thru valve ft @ sec.
Loss in head, ft.
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
1
2
3
4
5
6
7
8
9
10
11
12
Valve No. 3.
Heisler.
Area. 3.2 □"
Max. lift .54"
Velocity of 1 ft per sec. gives
discharge of .0222 cu. ft per sec.

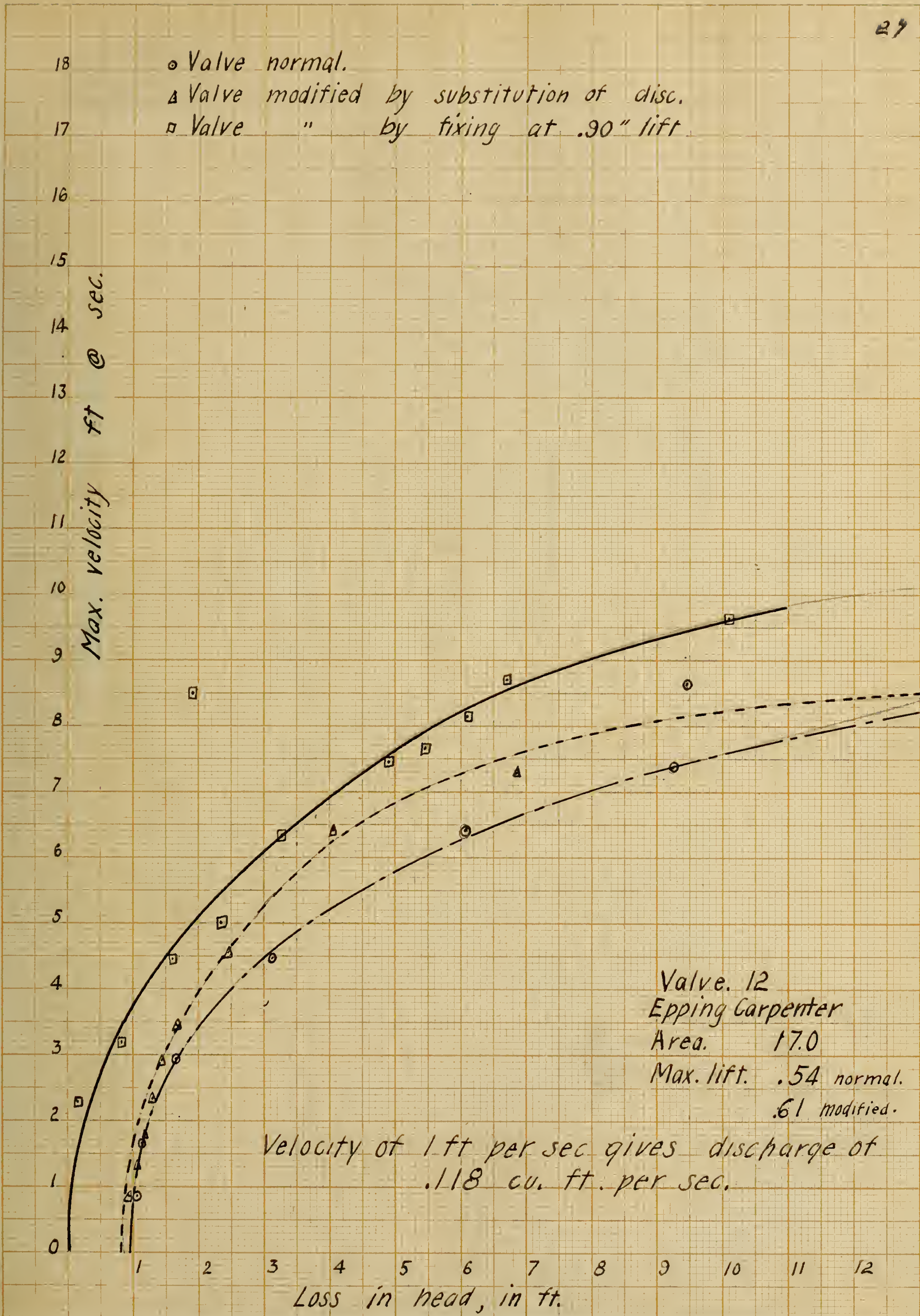


Max velocity thru, ft @ sec
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
1
2
3
4
5
6
7
8
9
10
11
12
Loss in head, in ft.
Δ Regulated at inlet.
⊙ Regulated at outlet
Valve No. 5
Union Steam Pump Co.
Area 5.6 □"
Max. lift .88"
Velocity of 1 ft per sec. gives discharge of .0390 cu. ft. per sec.

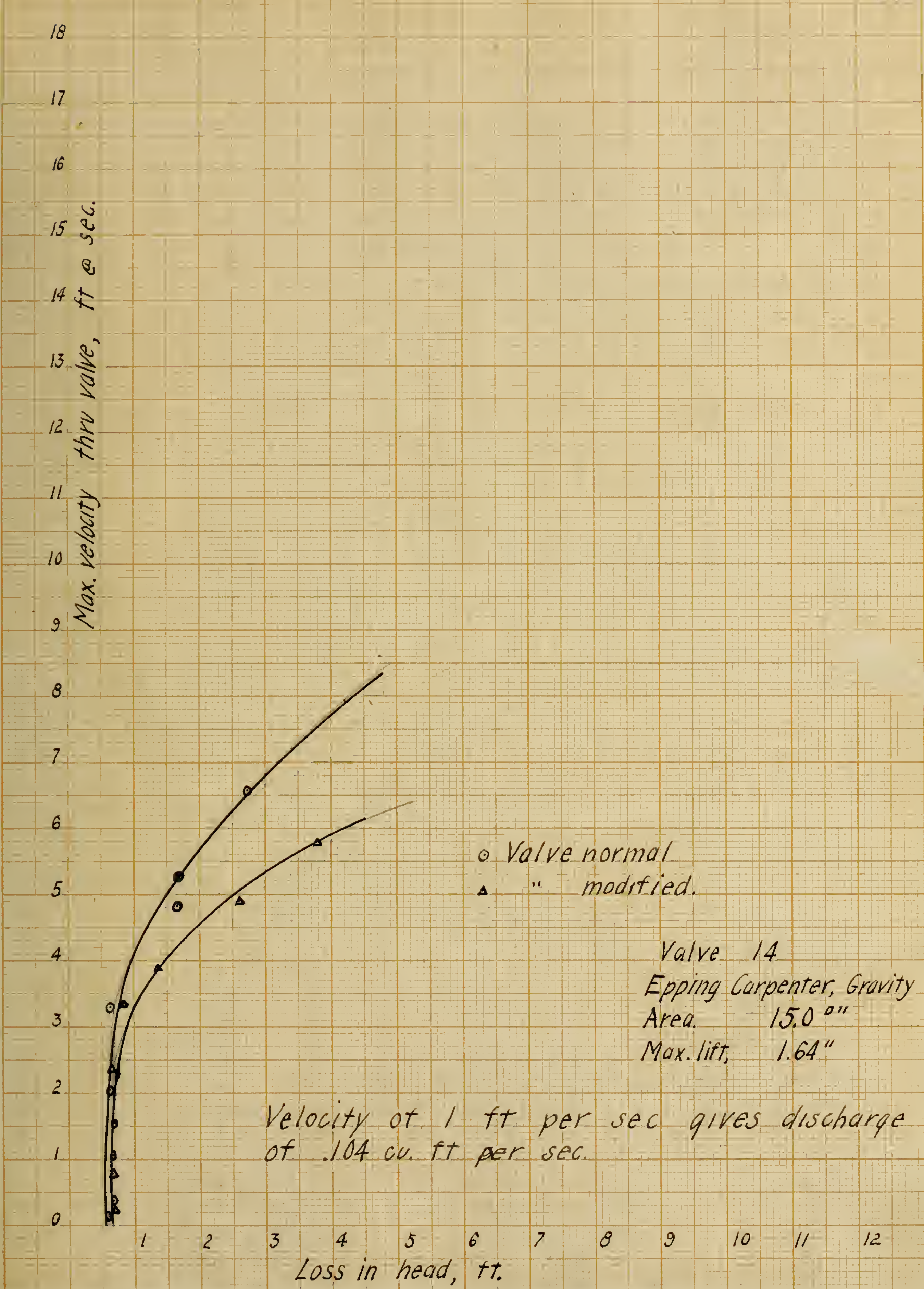

Max. velocity thru valve ft @ sec.
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
1
2
3
4
5
6
7
8
9
10
11
12
Loss in head, ft.
Valve No. 6
Snow.
Area. 6.91 □"
Max. lift .57"
Velocity of 1 ft per sec. gives discharge of .048 cu. ft per sec.

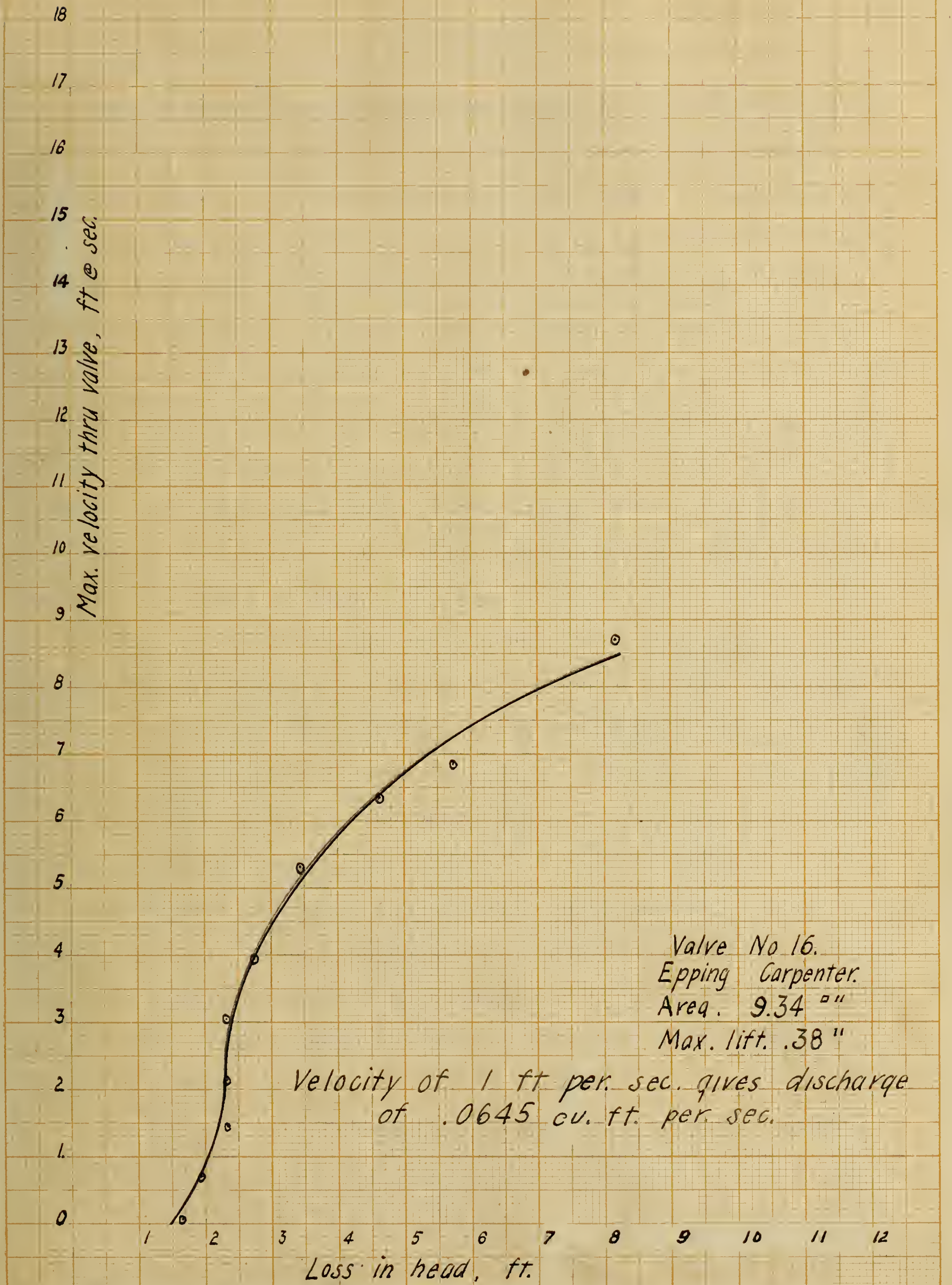

Max. velocity thru valve ft @ sec.
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
1
2
3
4
5
6
7
8
9
10
11
12
Loss in head, in ft.
Valve No. 8.
Snow
Area. 3.01 □"
Max. lift. .37"
Velocity of 1 ft per sec gives discharge
of .0209 cu ft per sec.


Maximum Velocity thru Valve, ft @ sec.
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
1
2
3
4
5
6
7
8
9
10
11
12
Loss in head, in ft.
Valve No. 10.
Epping Carpenter.
Area. 24.67 □"
Max. lift. .54
Velocity of 1 ft per sec. gives discharge of
.1715 cu. ft per sec.



⊙ Valve normal.
△ Valve modified by substitution of disc.
□ Valve " by fixing at .90" lift
Max. velocity ft @ sec.
Loss in head, in ft.
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
Valve. 12
Epping Carpenter
Area. 17.0
Max. lift. .54 normal.
.61 modified.
Velocity of 1 ft per sec gives discharge of .118 cu. ft. per sec.


Max. velocity thru valve, ft @ sec.
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
1
2
3
4
5
6
7
8
9
10
11
12
Loss in head, ft.
Valve normal
" modified.
Valve 14
Epping Carpenter, Gravity
Area. 15.0 □"
Max. lift, 1.64"
Velocity of 1 ft per sec gives discharge
of .104 cu. ft per sec.


Max. velocity thru valve, ft @ sec.
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1.
0
1
2
3
4
5
6
7
8
9
10
11
12
Loss in head, ft.
Valve No 16.
Epping Carpenter.
Area. 9.34 □"
Max. lift. .38"
Velocity of 1 ft per. sec. gives discharge
of .0645 cu. ft. per. sec.

CONCLUSIONS.

From these experiments not many definite conclusions can be arrived at, the apparatus is so different from that of actual practice, and the nature of the experiment makes it impossible to determine some things concerning the actual behavior of the valve. A pump valve must close quickly, since there is a very sudden change in the valve, in most makes of pumps at least, from high pressures to negative pressure. If the valve does not close quickly then there will be what is technically termed slip. An in consequence the pump will not deliver as much water as it seems to displace. In these experiments it was impossible to determine the rate of closing of a valve, and there was no attempt to determine the action of a valve in regard to slip.

This fact will perhaps explain why it is that some of the valves, as the Heisler No. 2, have such large losses; they are equipped with very heavy springs in an endeavor to make them close quickly, and are thus adapted for use in the case of a pump which runs at a high rate, as they would close quickly and avoid slip even if the loss was somewhat large.

In these experiments that gravity valve shows the least amount of head lost in proportion to the discharge, but this type of valve would be likely to close very slowly; for this reason the gravity type would be most adaptable to the slow pump where plenty of time for closing is left.

One thing that is shown is the need of some change in the apparatus by which more could actually be determined concerning the action of the valve. A glass handhole in the side of the valve chamber so that one could see what is going on, would be one im-

provement, as would a positive connection between the valve disk and the indicator which shows the amount of opening of the valve.

Three modifications of valves were considered. The first is illustrated with Epping-Carpenter valve No. 14, in which the corners of the cover were filled with neat Portland Cement, thus tending to make the passage through the valve more direct and without such sharp turns. It did not in the experiment reduce the loss to any appreciable extent. This is due very likely to the fact that there is an eddy caused by the sharp corner of the valve seat.

A second change is shown in Figure 2, Plate IV and illustrated by Epping-Carpenter valve No. 12, which was modified by the substitution of a larger disk than the one which regularly belonged to it. The edge of this large disk was beveled so that it made the loss of head less than it was with the regular valve disk. This substitution would also seem to make closure quicker, since there would be a larger area for the back pressure to work against.

The modification shown in Figure 3 was not made. This modification would have given the water a very direct passage through the valve and should have decreased the loss greatly. It would also have been difficult of mechanical construction and in practice could not be used on account of the fact that a disk of this type would not seat readily.

A comparison of the curves seems to show that in the valves where the ratio of compression in the spring to the area of the disk is small, the loss of head increases very slowly, while the discharge increases rapidly; but where the spring is stronger, the loss in head increases faster.

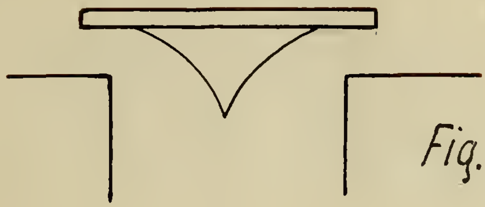


Fig. 1.

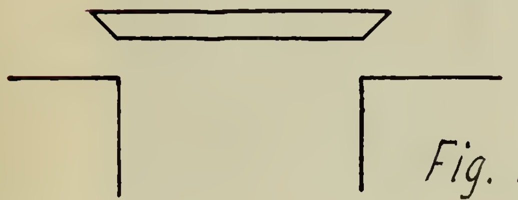


Fig. 2.

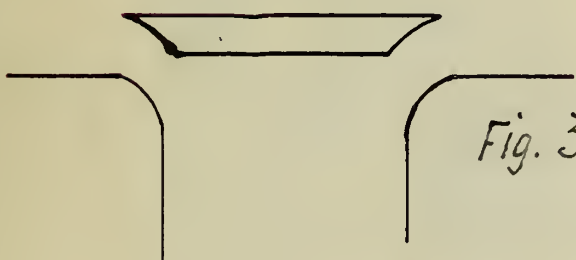
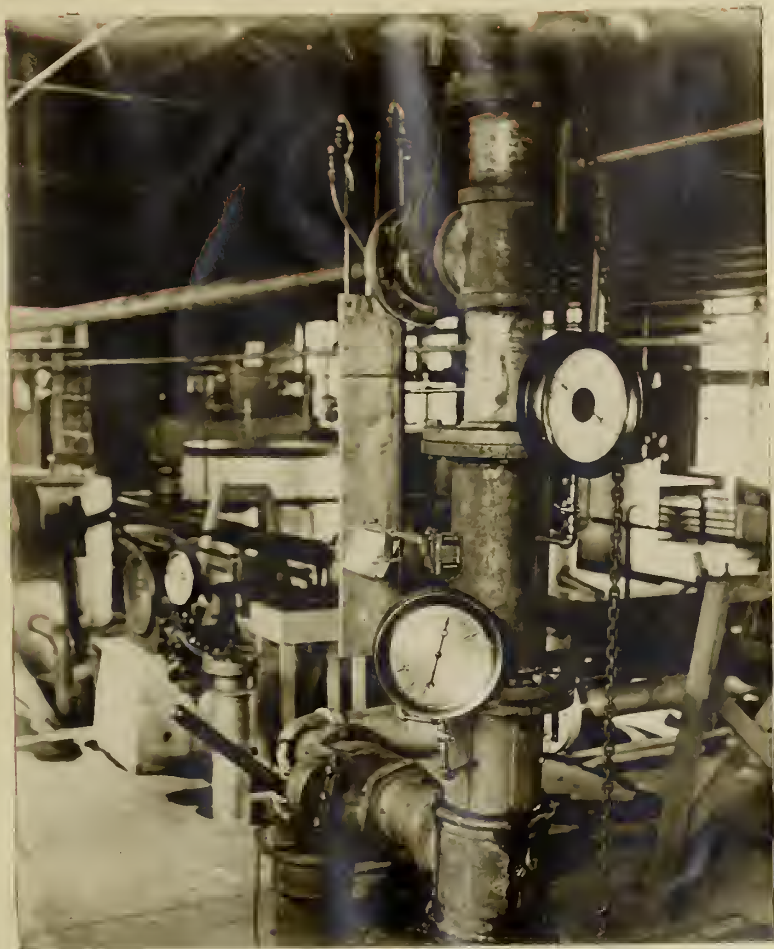


Fig. 3



VIEW OF APPARATUS.

VIEW OF APPARATUS.